

## Pitot tube in airplanes

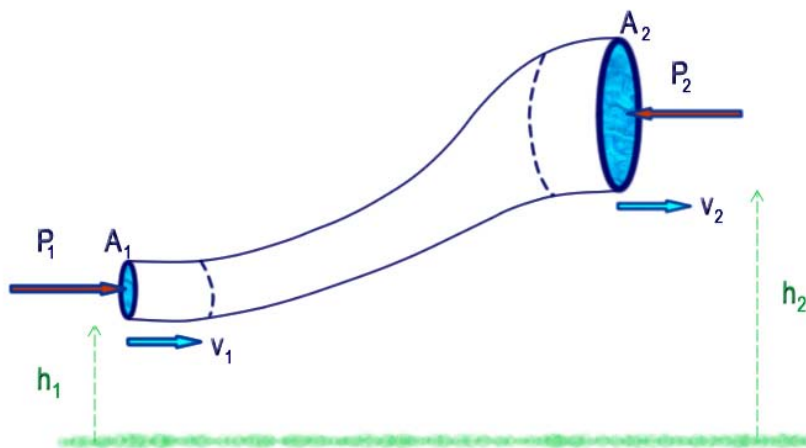
*Unfortunately I postpone the following article on the black holes to comment the operation of the tube of pitot, used to measure the speed in the airplanes. Subject of actuality before the disaster of the Air France Airbus A330. References: Tube of pitot, relative speed, equation of Bernoulli, sustentation airplane, Airbus A330.*

The pitot tube is used like instrument of measurement of the speed of the airplanes respect the air. It is necessary to consider that is exactly the relative speed between the airplane and the air (IAS, Indicated Air Speed), is the one that maintains to the airplane in flight, not it speed respect the ground (GS ground speed). The GPS gives to the speed of the airplane respect the ground and by means of the pitot tube the speed is obtained respect the air.

The speed of the airplane respect the air depends on the speed to the airplane respect the ground and the speed of the air. If the airplane moves with face wind must add the speed of the airplane with the speed of the air, this way it seems that the airplane moves faster. And indeed more fast, but respect the air, but slower respect the ground. How can be?, are things of the relative speed, imagine that you leave to walk a day of much wind, if the wind comes to you from face, then you noticed plus the wind and advanced more slowly. However if the wind pushes to you, then noticed except the wind and advanced faster. The same situation occur with an airplane.

The speed of the ground indicates to us how long the flight lasted and the airspeed gives the sustentation of the wing, that is what maintains to the airplane flying. It is necessary to consider in addition that the pressure diminishes with the height, since the amount of air is smaller as it increases the height of the atmosphere.

Let us see it in equations. The equation that models the behavior of the bodies in a fluid is the equation of Bernoulli. It is obtained applying the conservation of the kinetic energy and potential energy to a stream tube of flow according to the following drawing



The work  $W$  is force  $F$  by the distance  $d$ , in this case the force is the pressure  $p$  by the surface  $A$  and the surface by the distance is volume  $V$ .

$$W = Fd = pAd = pV$$

The work is the variation of the energy and in the case of the fluid tube, the work is obtained from the pressure differential. We obtain because the following equation that relates the work of pressure to the variation of the kinetic energy and the potential energy.

$$(p_1 - p_2)V = \frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2 + mgh_2 - mgh_1$$

$$p_1V + \frac{1}{2}mv_1^2 + mgh_1 = p_2V + \frac{1}{2}mv_2^2 + mgh_2$$

$$p_1 + \frac{1}{2}\rho v_1^2 + \rho gh_1 = p_2 + \frac{1}{2}\rho v_2^2 + \rho gh_2$$

$$p + \frac{1}{2}\rho v^2 + \rho gh = cte$$

This is the Bernoulli's equation.

Applying the equation of Bernoulli to the wing of an airplane we can despise the term of the variation of the potential energy since we can suppose that the height is the same one. The wing is designed of way that the air that flows over the wing is faster on the wing that under the wing. This is obtained designing the superior surface of greater area than the inferior one, with this the distance that it has to cross the upper air is greater than the inferior one, since they cannot be empty, the molecules in the superior part of the wing go to faster than the air molecules in the inferior part of the wing.

The sustentation of an airplane



$$p_1 + \frac{1}{2}\rho v_1^2 = p_2 + \frac{1}{2}\rho v_2^2$$

$$p_2 - p_1 = \frac{1}{2}\rho(v_1^2 - v_2^2)$$

Since the speed under the wing ( $v_2$ ) is minor than upper the wing ( $v_1$ ), the pressure under the wing is greater than on the wing, so that the wing stays floating, this is the lift force of the airplane. Another way to understand how an airplane stays floating in the air is from the laws of Newton. When moving the airplane, the air hits against the slightly inclined wing, pushes the air downwards and by the third law of Newton (action-reaction) the wing is impelled upwards.

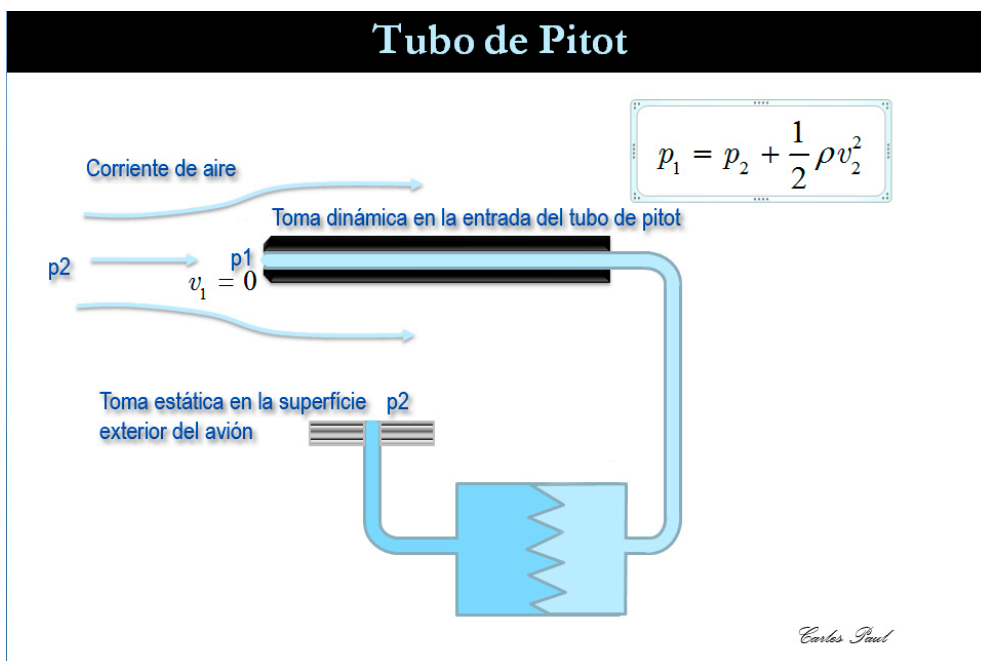
If the air cannot flow uniformly by the wing, turbulences take place that reduce the sustentation and the wing enters lost, that is to say, the airplane stalls.

The Airbus A330 flew to a height of about 11000 meters, to the limit of its maximum altitude. To that height the air is much less dense, is less air molecules and consequently the sustentation of the airplane is much more critical with the speed since they pass less molecules through the wings. The airplane must move at greater speed to generate the sustentation necessary to maintain the ship to this altitude.

It is necessary to go with well-taken care of since the structural resistance of the wings of the airplane does not support to speeds superior to the sound (mach 1), about 340 m/s or 1225 km/h, is what it is known like sound barrier, at the level of the sea. With the height this speed diminishes, it's consequence of which there is less molecules and the temperature is smaller. To the height of 11000 meters the sonic speed is of 295 m/s or 1062 km/h.

Pay attention that when increasing the height is needed greater speed to obtain the sustentation of the wing but the sonic speed to this height cannot be exceeded. It is necessary to watch because the speed at which the airplane moves respect the air. So that one flies to these heights? there are different reasons but I believe that the main one is the economic one, as the air is less dense, the drag is smaller and less fuel is spent.

The pitot tube serves then to know what speed the airplane hits against the air. Its operation is also based on the equation of Bernoulli and take built-in systems of heating to avoid that they freeze and the ram air is obstructed.



$$p_1 = p_2 + \frac{1}{2} \rho v_2^2$$

$$p_1 - p_2 = \frac{1}{2} \rho v_2^2 \Rightarrow v_2 = \sqrt{\frac{2(p_1 - p_2)}{\rho}}$$

The pitot tube measures the speed to divide of the pressure differential between the point 1 and point 2. By an end the air impelled by the speed of the airplane enters point 1 and the pressure in 2 is the outer atmospheric pressure that is moderate through the non-ramming intake, located in a lateral one of the plane. Both pressures agree in a camera where the pressure differential is moderate, dynamic pressure is denominated.

Another problem at this point of cruise is the low temperature and the bad meteorological conditions. In normal conditions there is no problem in flying to 11000 meters while the air has a smooth behavior. In case of storm the maneuver margin of the airplane is more restricted. And in the Pacific, exactly near the equator where the winds of the north with those of the south are united the storms are but strong, by that all intercontinental airplanes have meteorological radar in the nose of the airplane, to detect storms and to draw for them.

It's says that the airplane did not fly to the a suitable speed because the pitot tubes froze and gave to an incorrect signal of the speed of the airplane respect the air, when interpreting erroneously the dynamic pressure. Remember that if the speed is low it loses sustentation and the airplane stalls and if the speed is too high it appears the problem of the structural resistance.

It seems to be that the model of pitot's tube of the Thales mark PN C16195BA were defective and they had to change by new PN C16195A or those of the competing mark Goodrich. The new tubes of pitot arrived three days before the disaster.

If the crew and the security systems thought that they flew at a speed different from the real one, along with a strong storm and the limitations of security imposed by the height...

But until the black boxes will found and the investigating finished are speculations. I have only tried to clarify the basic principles of the mechanics of fluids that maintains to an airplane and how the pitot tubes work. The reality is much more complex.